Comparative Performance Evaluation of EDCF and EY-NPMA Protocols

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***Abstract*—Medium access represents one of the most critical building blocks regarding the performance of a wireless LAN. In this letter, we compare the performance of two well-known medium access control protocols specifically developed for the wireless environment, EDCF and EY-NPMA. To our knowledge, it is the first time that these two quality-of-service (QoS) aware medium access schemes are compared. Furthermore, we propose a novel scheme for medium access based on EY-NPMA, that demonstrates reduced overhead compared to the base protocol and better utilization of the common medium. The conclusions of this paper are based on extensive simulation trials.**

***Index Terms*—Enhanced distributed coordination function (EDCF), elimination-yield non-preemptive medium access (EY-NPMA), medium access, wireless LANs.**

I. Introduction

RECENTLY, wireless LANs have known an impressive increase in popularity. The advances in microelectronics have allowed the design and construction of powerful computing devices with small footprint (notebooks, PDAs, etc.), while novel physical layer techniques have made possible the introduction of wireless LANs which support bitrates that until recently were attainable only in their wired counterparts. These two factors, combined with the increasing penetration of the Internet in every day activities, have transformed the wireless LANs market from niche to mass market.

In this letter, we measure the performance and compare two well-known medium access control protocols specifically developed for the wireless medium, namely, Enhanced Distributed Coordination Function (EDCF) [1] and EY-NPMA [2]. As far as we know, this is the first time that these access protocols are compared. Further, we propose and describe a novel medium access scheme based on EY-NPMA, that reduces the overhead that accompanies the base scheme with positive consequences in its performance. Extended simulation trials were conducted in order to measure the performance of all three protocols.

II. Description of the Protocols

A. Enhanced Distributed Coordination Function (EDCF)

Enhanced distributed coordination function (EDCF) is a protocol that is still under development by the task group E of the IEEE 802.11 working group for wireless LANs. EDCF is an extension of the DCF scheme of the base 802.11 [3] protocol, embedding quality of service (QoS) functionality in it, yet remaining compatible with DCF.

EDCF provides differentiated behavior to different traffic classes by introducing two modifications to the DCF. First, there are no global CWmin and CWmax values, rather each traffic class i has its own contention window limits, $\mathrm{CW}\min[i]$ and $\mathrm{CW}\max[i]$. High priority traffic employs lower values for CWmin and CWmax than low priority traffic, having thus a higher probability for making a transmission attempt. The second measure that is used to further differentiate the behavior of EDCF to different traffic classes is the introduction of the arbitrary interframe spaces (AIFS). Instead of using DIFS for each traffic class, the backoff counter of traffic class i may begin decrementing after $\mathrm{AIFS}[i]$ time has passed from the end of the last transmitted frame. By letting low priority traffic have longer AIFS, differentiation is provided.

B. Elimination-Yield Non-Preemptive Medium Access (EY-NPMA)

Elimination-yield non-preemptive medium access (EY-NPMA) is a medium access control protocol standardized under ETSIs HIPERLAN/1. According to EY-NPMA, time is divided into cycles, each cycle consisting of four distinct phases: 1) prioritization; 2) elimination; 3) yielding; and 4) data transmission. EY-NPMA supports five distinct priorities, with 0 being the highest and 4 the lowest.

At the beginning of each cycle, each station senses the common medium for as many slots as the priority of the packet in its buffer. All stations that sense the medium as idle for the whole interval, start transmitting an energy burst, while those that do not exit the contention process. Consequently, at the end of the prioritization phase only the stations with the highest priority packets at the time stay in the contention process. The elimination phase commences when the stations begin to burst. Each station bursts for a random number of time slots that follows a truncated geometric distribution. Immediately after bursting, each station senses the channel. If the medium is sensed as idle, the station continues to the next phase, yielding. At the end of the elimination phase, at least one station will have survived and will proceed to the yielding phase. All stations that have survived elimination pick up a random number of slots to backoff according to a uniform distribution. The station that backs off for the fewer slots, accesses the channel, while all others refrain from transmitting.

Through this four-phase scheme, EY-NPMA manages to achieve low collision probabilities. The parameters chosen at the standard aimed at providing a collision probability of 3.5% for 256 simultaneously contending stations, although this performance came at a cost of high overhead. The performance

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of EY-NPMA has been studied analytically in [4], while it has been compared to DCF in [5].

C. EY-NPMA/ZP

Aiming at enhancing the performance of EY-NPMA, we propose a novel scheme for medium access based on it, named EY-NPMA/ZP (ZP stands for zeroed priority). EY-NPMA/ZP employs a mechanism for dynamically upgrading the priority of a subset of stations to the highest priority (i.e., 0), in order to avoid the heavy contention at their original priorities. EY-NPMA/ZP is based on the assumption that the highest priority class is mainly used for network management and signalling purposes, hence being unpopulated. If actual transmissions are made in 0 priority, we expect them to be much fewer than the number of transmissions in all other priorities.

According to this scheme, all stations that survive elimination upgrade their packets' priorities temporarily to zero and make a few attempts at the highest possible priority. An upgraded station falls back to its original priority if it successfully transmits a packet or a total number of N_0 cycles are made in zero priority. There are two main benefits from this temporary priority upgrade. First, for all cycles in zero priority, there is no overhead in the form of prioritization slots, since the upgraded stations burst as soon as possible. Second, by letting only a subset of stations to enter the contention process (those that have survived elimination in a previous cycle), the elimination phase becomes on average shorter, while there are more favorable probabilities for successful transmissions.

However, the obvious disadvantage of this method is that while a subset of stations is upgraded to the highest possible priority, traffic originally placed at this priority will meet some extra competition, while all lower priority stations will be prohibited from making attempts to access the channel. It should be pointed out, however, that in order to get upgraded, a subset of stations must survive from being eliminated in a cycle of their original priority. At the time these stations get upgraded, they will have the highest priority data amongst the network population. Consequently, the above mentioned inter-priority interference applies only to packets that arrive after these stations upgrade their priorities. By choosing a relatively small value for N_0, the stations stay upgraded for a short interval and the interference between the different priorities is minimal.

III. Simulation

A. Simulation Scenario

The results used to compare the three medium access protocols were obtained using a custom simulation tool developed by the authors. The simulations aimed at comparing the medium access mechanisms and not the respective implementations, as expressed in the standards. Toward this end, we assumed a channel rate of 20 Mb/s, while the slot time was set to 10 μs for all three protocols. All stations were within range of each other, consequently there were no hidden node occurances. The offered load consisted of three sources placed at each station participating in the network. The high priority source generated 160 bytes long packets every 10 ms, while the medium and the low priority sources generated 400 bytes long packets according to a poisson process with a mean packet interarrival time equal to 10 ms.

TABLE I
Parameters Used for EDCF

	TrafficClass		
	High	Medium	Low
AIFS	1	4	11
CWmin	3	19	19
CWmax	511	1021	1021

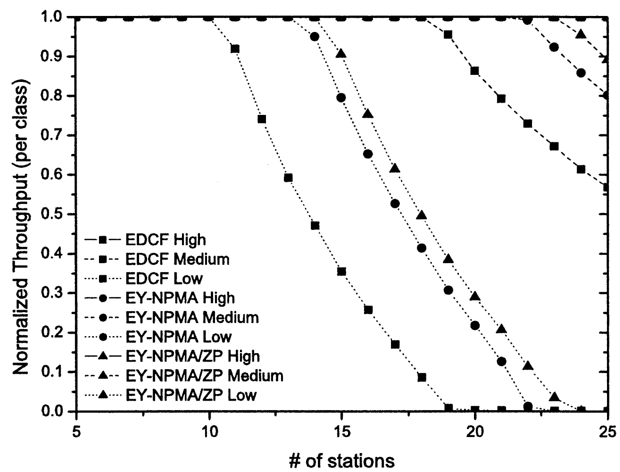

Fig. 1. Normalized throughput versus the number of stations.

In order to ensure a fair comparison between the three medium access schemes, the parameters used for each protocol were the optimal ones for this scenario. The objective function that was used for the optimization process expressed the aggregate throughput of all three traffic classes, each class participating with a different weight in the sum, according to its priority. Specifically, for EDCF, Table I summarizes the parameters that were used throughout the simulation trials. For the base EY-NPMA scheme, we allowed maximum 3 slots for bursting, 5 slots for yielding, while the probability for bursting for one more slot was set to 0.3. For the EY-NPMA/ZP protocol, the parameters used for the normal cycles were different than those used for the upgraded cycles. Specifically, for normal cycles the parameters were (3, 5, 0.3), while for upgraded cycles the parameters used were (2, 4, 0.4). Finally, the maximum number of transmission attempts that could be made while upgraded (N_0) was set to 5.

B. Simulation Results

In Fig. 1, we present the normalized throughput per traffic class as the network population increases. From this graph, it is confirmed that all three medium access schemes provide service differentiation. As the network becomes more populated, the throughput of the low priority streams decreases, while all high priority packets get delivered for all network populations. On the other hand, both EY-NPMA and EY-NPMA/ZP completely lead to starvation of low priority streams, since all low priority stations exit the access cycle at the prioritization phase. The net result of this is that with EDCF collisions between packets of different priorities is possible, while with EY-NPMA and its variant it is not. Under this scenario, the highest performing scheme was EY-NPMA/ZP, being followed by the base EY-NPMA scheme, while EDCF performed much worse than

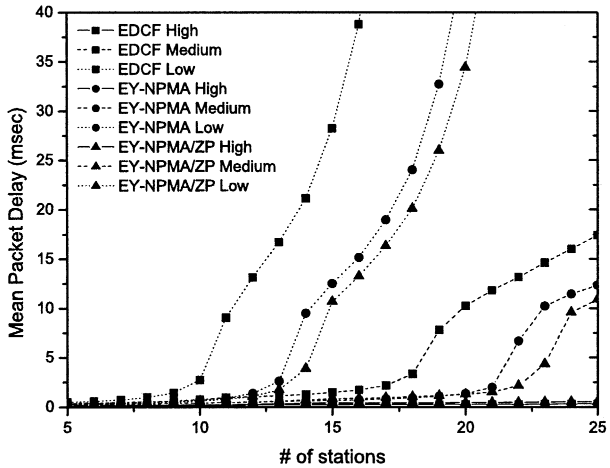

Fig. 2. Mean packet delay versus the number of stations.

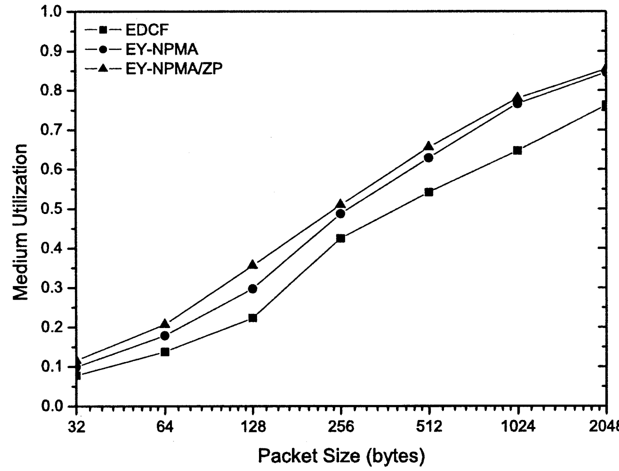

Fig. 3. Medium utilization vs packet size.

TABLE II
DELAY STATISTICS FOR 25 STATIONS

	Highpriority		Mediumpriority	
	T	T_{99}	T	T_{99}
EDCF	0.3ms	1.6ms	17.4ms	275ms
EY-NPMA	0.3ms	0.75ms	12.4ms	56ms
EY-NPMA/ZP	0.5ms	1.7ms	10.9ms	47ms

the other two. This is primarily owed to the two-stage scheme (elimination, yielding) used for access resolution by EY-NPMA and EY-NPMA/ZP, while prioritization ensured that only the highest priority stations contended for channel access. Furthermore, the temporary upgrade of some stations to the highest priority employed by EY-NPMA/ZP reduced the overhead and increased the medium utilization compared to the base EY-NPMA scheme.

In Fig. 2, we present the mean packet delay per traffic class as the network population increases. Packet delay is defined as the interval between the arrival of a packet to the head of the respective priority queue and the successful acknowledgment of its reception. As hinted by Fig. 1, EY-NPMA/ZP generally achieved the highest performance, while EDCF showed higher delay figures compared to the other two protocols. For all network configurations, however, the mean packet delay for the high priority streams stayed well below the 1-ms threshold for all three protocols examined. As mentioned in the protocols description section, EY-NPMA/ZP slightly alters the priorities balance, by temporarily upgrading lower priorities to zero. This may cause increased jitter and increased delay figures for high priority traffic. In Table II, we provide the mean packet delay for the high and medium traffic classes (T) and the respective threshold, compared to which 99% of the delivered packets have lower delay (T_{99}).

The results of Table II show that upgrading the priority of low priority stations, as was the case with EY-NPMA/ZP, did not affect jitter significantly. Also, we notice that in the case of high priority traffic, EY-NPMA/ZP demonstrated longer delays compared to the other two schemes. It is clear, therefore, that the lower delays observed at lower priority streams, came at a cost of slightly increased delay for high priority packets.

Fig. 3 presents the medium utilization under different packet lengths. For this scenario, we considered a network population of 25 stations. At each station, three identical sources were attached, one for each priority queue. The same packet arrival rate was applied to each source, chosen so that the aggregate offered load would be equal to the channel rate, that is 20 Mbps. Compared to each other, EY-NPMA/ZP shows the best performance, followed by the base EY-NPMA scheme. From this figure it is evident that all three schemes show better performance for longer packets. This was expected, since as the packet size increases, the access overhead (in the form of bursting and/or backoff slots) becomes less significant compared to the longer data transmissions. For the same reason, we notice that for long data packets the difference between the EY-NPMA and EY-NPMA/ZP decreases.

IV. CONCLUSIONS

In this letter, we described and measured the performance of three protocols specifically developed for the wireless environment. EDCF, EY-NPMA and EY-NPMA/ZP were tested through extensive simulation trials and were evaluated using the metrics of throughput and mean packet delay. Our simulation results showed that the two-stage access resolution of both EY-NPMA and its variant allowed them to perform better than EDCF, which employs a single backoff stage to determine which station accesses the common medium medium. Furthermore, the same simulations showed that EY-NPMA/ZP is a positive modification to EY-NPMA.

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